Southern African Large Telescope

Title: **MIDAS automatic pipeline for HRS data**

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ABSTRACT

In this report I present the MIDAS automatic pipeline for the High Resolution Spectrograph (HRS) data obtained in LR, MR and HR modes. If you would like to look on your reduced HRS data, you are welcome to read this short report to understand: (1) the general information about pipeline and (2) the output data structure and filename convention. ***Enjoy your reduced HRS data!***

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1 Introduction

I presented in my previous reports (Kniazev, 2016a,b,c,d) some MIDAS programs which I used for the reduction of HRS data. I combined these previously described programs using UNIX Shell into MIDAS automatic pipeline for HRS data. The report (Kniazev, 2016e) presents the absolute accuracy of radial velocities measured with this pipeline. I will describe briefly in this report the structure of the package and its input/output.

2 General Description

All programs are written in MCL (MIDAS Command Language) and UNIX Shell. The low level consist of MIDAS programs only. The next level are UNIX Shell files, which call MIDAS programs.

2.1 The MIDAS level

MIDAS level is responsible for the HRS data reduction.

For Red arm data and Blue arm data in each HRS mode all programs are combined into three main procedures:

1. **FLAT reduction**
   During this step HRS FLAT image is reduced. The output of this procedure consist of (1) FITS table with centers of all found orders positions; (2) extracted and smoothed flats for both fibers; and (3) file with flats ratio.

2. **ARC reduction**
   During this step HRS ARC image is reduced. The output consist of all tables, which are necessary for wavelength calibration of both fibers and extracted, calibrated and merged ThAr+Ar spectra for both fibers.

3. **Object reduction** The output consist of extracted, calibrated and merged spectra for both fibers and result of subtraction of the sky fiber from the object fiber as well as extracted, calibrated but not merged spectra for both fibers.

The output of all procedures is mostly FITS-files except configuration files, which are saved by system in the internal MIDAS format.

Each of the above procedures has as at minimum two modes of work: (1) **visualization mode**, when practically after each step user has a possibility to see and check the result of step, and (2) **silent mode**, when procedures work without any graphical output. Only the ARC reduction procedure has one more interactive mode for the possibility of re-identification of the reference spectrum.

2.2 The UNIX shell level

The UNIX shell layer is responsible for the:

1. Creation of the correct directories structure;

2. Coping data into temporary directory for the reduction and coping data after reduction into correct directories and making symbolic links;

3. Analysis of FITS files after primary data reduction and grouping these files into FLATs, Arcs and OBJECTs obtained with different modes and arms for the current night.

2.3 MIDAS HRS pipeline possibilities

The basic program gives a possibility to reduce HRS data from one observational night.

The next layer program gives a possibility to reduce HRS data for one month.

There is a possibility to reduce HRS data for: (1) one file only; (2) one science program only; (3) one HRS arm only.

3 Data Structure

3.1 Input Data

Input data for the MIDAS HRS pipeline are FITS files from SALT archive after primary data reduction with the SALT science pipeline (Crawford et al. , 2010). This includes BIAS, OVERSCAN and GAIN corrections.

Input names have standard names like mbgphH201506220014.fits or mbgphR201506220014.fits, where first letters 'mbgph' shows different steps of primary data reduction, letters 'H' or 'R' relate to the Blue and Red arm data, and following numbers describe date of observations and relative number of exposure during the night.

3.2 Output Data

Since size of output data is MUCH less compare to the size of input 2D echelle spectra MIDAS HRS pipeline produces many different output files, which users can use for different sort of analysis.

For each input files like 'mbgphH201506220014.fits' MIDAS HRS pipeline produces following output FITS files:

mbgphH201506220014_1w.fits – extracted first fiber. Wavelength calibrated. Not merged. 2D spectrum, where each order is one line in 2D spectrum. This is the most compact format, but only MIDAS can understand it easily. See Section 5 for more information.

mbgphH201506220014_2w.fits – the same for the second fiber. 2D spectrum. MIDAS format for echelle data.

mbgphH201506220014_1we.fits – as above, but each order is written as separate FITS

extension. FITS file has as many extensions as extracted orders. Can be easily understand by IRAF, where all programs can work with FITS extensions in the format i.e. 'mbgphH201506220014_1we.fits[1]' – for the first one. MIDAS understand it as well.

mbgphH201506220014_2we.fits – the same for the second fiber. 2D FITS spectrum with many extensions. Both MIDAS and IRAF understand it.

mbgphH201506220014_1wm.fits – extracted first fiber, wavelength calibrated and merged. 1D FITS spectrum. Both MIDAS and IRAF understand it.

mbgphH201506220014_2wm.fits – the same for the second fiber. 1D spectrum. Both MIDAS and IRAF understand it.

mbgphH201506220014_u1w.fits – extracted first fiber and divided to the flat. Wavelength calibrated. Not merged. 2D spectrum, where each order is one line in 2D spectrum. MIDAS format for echelle data. See Section 5 for more information.

mbgphH201506220014_u2w.fits – the same for the second fiber. 2D spectrum. MIDAS format for echelle data.

mbgphH201506220014_u1we.fits – as above, but each order is written as separate FITS extension. Can be easily understand by IRAF. 2D FITS spectrum with many extensions.

mbgphH201506220014_u2we.fits – the same for the second fiber. 2D FITS spectrum with many extensions. Can be easily understand by IRAF.

mbgphH201506220014_u1wm.fits – extracted first fiber, divided to the flat, wavelength calibrated and merged. 1D FITS spectrum. Both MIDAS and IRAF understand it.

mbgphH201506220014_u2wm.fits – the same for the second fiber. 1D FITS spectrum. Both MIDAS and IRAF understand it.

mbgphH201506220014_uwm.fits – the final result after sky fiber was subtracted from the object fiber. 1D spectrum. Both MIDAS and IRAF understand it.

Additionally, for each reduced science object, system forms PDF-picture, showing the Signal-to-Noise ratio for collected data. In case input file with name **'mbgphH201506220014.fits'** such picture will have name **'mbgphH201506220014_2wm.fits_SNR.ps'** in case LR data and **'mbgphH201506220014_1wm.fits_SNR.ps'** in case of MR and HR data. It reflect the fact that second fiber is object fiber in case of LR, but the first fiber in case of MR and HR data.

4 Some notes for regular users

1. Since I have created this pipeline for my own data I found that it is useful to calculate heliocentric correction **for each** spectrum taken. So **each** FITS-file contains a descriptor

with this number. This descriptor has the name HEL_COR and you need to add its value to any velocity you will calculate for these data to take into account heliocentric correction. Units are 'km/s'.

2. MIDAS HRS pipeline automatically calculates the velocity for all velocity standards that were observed to check HRS stability. It is done via Fourier cross correlation with model spectra of stars. I am in the process of implementing such a calculation for *any* spectrum which is reduced with this pipeline. You are welcome to check for these descriptors in the FITS headers. *If* such descriptors exist in your data, they contain the following information:

   VEL_HW – the calculated heliocentric velocity in units 'km/s'

   VEL_HWE – the error for calculated heliocentric velocity in units 'km/s'

3. Since it is very difficult to know in advance which sort of data are most useful for users, the MIDAS HRS pipeline retains and provides all possible information. You may need only part of the information and have to decide yourself which type of data are useful to you. Please, take into account that:

   - Files without division by the flat are useful to understand how many counts were collected. After data were divided by flats, you only have relative counts.
   - If the exposure was very short, *or* in case of the Blue arm data, with very high probability you will need only OBJECT fibers.
   - If the exposure was long enough, and/or it is Red arm data, you will possibly need the result of the subtraction of the sky fiber from the object fiber.
   - The result of merging (all files named 'm*m.fits') is not yet ideal. If you will not like it, please work with 'm*e.fits' files.
   - As I wrote above, all files 'm*m.fits' are just normal 1D spectra and both IRAF and MIDAS can work with them.

5 Some notes for experienced users

In case you are an experienced user and would like to work with 'm*w.fits' FITS files, you need to understand its structure. It is very simple. They are 2D spectra, where each row belongs to one extracted order. In this case the FITS header contains additional information:

- Wavelength step is written into FITS descriptor CDELT1.
- **WSTART** for each order is written in the FITS descriptor HISTORY in the form:

```
HISTORY 'WSTART','R*8',1,36,'3E23.15'
HISTORY    3.893187746840700E+03  3.925598251079400E+03 3.959389762156500E+03
HISTORY    3.993526524943200E+03  4.028310634685401E+03 4.063698934919400E+03
```

```
HISTORY    4.099691425645200E+03  4.136590202108700E+03 4.173661604427000E+03
HISTORY    4.211639292483001E+03  4.250307483958200E+03 4.289709335316300E+03
HISTORY    4.329844846557300E+03  4.370714017681200E+03 4.412403161615401E+03
HISTORY    4.455602781779100E+03  4.498111898523600E+03 4.542260960888700E+03
HISTORY    4.587229996064100E+03  4.633148473440900E+03 4.679973236555400E+03
HISTORY    4.727704285407600E+03  4.776471089388600E+03 4.826230492034700E+03
HISTORY    4.877025649809600E+03  4.928942875640701E+03 4.981895856600600E+03
HISTORY    5.036014062080400E+03  5.091340648543801E+03 5.147961928918200E+03
HISTORY    5.205748433812500E+03  5.264872789081500E+03 5.325334994725200E+03
HISTORY    5.387264520134700E+03  5.450531895918900E+03 5.515309747932600E+03
```

- The total amount of points for each order is written in the FITS descriptor HISTORY in the form:

```
HISTORY 'NPTOT','I*4',1,36,'7I10'
HISTORY        1176      1202      1205      1214      1222 1231      1248
HISTORY        1240      1258      1267      1277      1287 1297      1307
HISTORY        1317      1310      1340      1351      1363 1375      1388
HISTORY        1401      1414      1428      1442      1456 1472      1488
HISTORY        1504      1519      1537      1554      1573 1588      1612
HISTORY        1634
```

- And absolute order number is written in the FITS descriptor HISTORY in the form:

```
HISTORY 'NORDER','I*4',1,36,'7I10'
HISTORY         119       118       117       116       115 114       113
HISTORY         112       111       110       109       108 107       106
HISTORY         105       104       103       102       101 100        99
HISTORY          98        97        96        95        94 93         92
HISTORY          91        90        89        88        87 86         85
HISTORY          84
```

6 Future development

1. As I wrote in Section 4, I am in the process of implementing an automatic cross-correlation for each reduced spectrum. Unfortunately, it is not a very stable procedure and I'm trying to understand simple criteria of its usability.

2. MIDAS has optimal extraction as well. I have a plan to implement it in case I will have time.

7 Conclusions

Enjoy your reduced HRS data!

References

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